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June 25, 2021

Ms. Jamie Lancaster
Surface Mining Unit Manager
Georgia Department of Natural Resources
Environmental Protection Division
4244 International Parkway; Suite 104
Atlanta, Georgia 30354

Re: Response to Comments
Twin Pines Minerals, LLC Permit Coordination Document
Mine Name: Saunders Demonstration Mine
County: Charlton

Dear Ms. Lancaster:

Twin Pines Minerals, LLC (TPM) has reviewed the Twin Pines Permit Coordination Document provided by the EPD, dated April 14, 2021, and offers the following responses. Each comment is repeated below, followed by TPM's response.

1. ***<u>Surface Mining Application and Mining Land Use Plan Review Comments by Surface Mining Unit (Contains most MLUP sheets)</u>***

   a. *Please add Mine ID No. 2073 to each sheet or Figure.*

      Response: Done. The Mine ID has been added to the title block of each sheet and figure of Surface Mining Land Use Plan (MLUP).

   b. <u>Land Use Development Plan</u>

      i. *On page 5 in the last paragraph with the sentence starting "In the PCP…", please ensure that "spiral concentrate" is the correct language.*

      Response: Done – Sheet 14 – Supplemental Text – Page 5. The language has been corrected to read, "In the PCP, spirals will be used to separate the heavy mineral sands from the lighter clays and quartz sand."

      ii. *On page 6, Section VI, please be aware that a radioactive handling permit may be necessary. Surrounding mines have come across a need for one due to uncovering natural occurring radioactive materials.*

      Response: TPM is aware that a radioactive material handling permit may be required if naturally occurring radioactive material is concentrated to a level that exceeds the regulatory threshold.

iii. *In Section X, which begins on page 10, please edit this section to note that any additional mining operations not included in this demonstration mine will require a new set of permits and a full permitting process.*

Response: Done. The following statement was added to Sheet 14 – Supplemental Text – Page 8, "TPM acknowledges that additional mining operations not included in this demonstration mine will require a new set of permits and a full permitting process.

c. *Figure 3: Proposed Site Layout*

i. *There are tailing stockpiles in the southwest corner. Please provide detail regarding runoff from this stockpile area. Will the stockpile move along with mine progression?*

Response: Done. The following note has been added to Sheet 3: "Tails stockpile and conveyors shall move in accordance with the moving mine pit and are not permanent features; runoff shall be controlled by berms, silt fence, hay bales or any combination thereof". Erosion and sediment control for stockpiles are detailed on Sheet 7.

ii. *Please add a note or another page for mine progression and how the portable conveyors will move along with the stockpiles. Will the stockpiles move along with the conveyors?*

Response: Done. The note added to Sheet 3 (discussed above) also explains that the portable conveyors will also move with the mine pit as it progresses.

iii. *Add a construction exit to the entrances of the plant and pumping well. Both are off Hwy 94. Please provide details of the construction exits on the detail sheet.*

Response: Done. Call-outs have been added for construction exits to be located at Highway 94 leading to the processing plant and FPW-01 (Sheet 6). The note also refers to the detail of the construction exit located on Sheet 7.

iv. *Please label each pumping well.*

Response: Done -Sheet 3.

d. *Figure 5: Process Flow Diagram*

i. *Add "permitted outfall" to heavy rain event discharge arrow.*

Response: Done – Sheet 5.

ii. *Add a description of how the material is transported from the Mineral Concentrate Stockpile to the Mineral Separation Plant or Direct Sale, e.g. trucking or conveyor. Show any piping between the Mineral Separation Plant and the main Permit Area. Does Mineral Separation Plant need to be on Surface Mine Permit? If so, please show or explain how the material is being transported to the Mineral Separation Plan. (ie. From Figure 3&5).*

Response: Done. A pipe feature has been added to Sheet 3 where the pipe will lead from FPW-01 to Highway 94 (within the permit boundary), and call-out text has been added to show the continuation of the pipe to the Mineral Separation Plant (MSP) outside of the permit boundary. A note has also been added to Sheet 5 that addresses piping/hauling. The MSP has been removed from the Permit Area.

e. *Figure 6B: Mining Profile/Cross-section (Typical)*
   i. *Please note the average timeframe that this backfilling process will take. This may be a range*.

   Response: Done – Sheet 5. A note has been added to address the movement of the mine and the timeframe of the initial backfill process.

f. *Figure 10: Post Mining Restoration Plan*
   i. *Please rename Figure 10 to Reclamation Plan.*

   Response: Done – Sheets 8 and 9 are now titled Reclamation Plan.

   ii. *On a separate sheet, if necessary, provide, to scale, the North South cross section trace through the permitted reclaimed mine that includes the appropriate parcels, berms, undisturbed buffers, Georgia Highway 94, and Norfolk Southern Railroad. Also include, to scale, the East West cross section that includes undisturbed buffers, T-Model and Trail Ridge Roads.*

   Response: Done. Section A-A' (east-west) and Section B-B' (south-north) cross-sections have been added to Sheet 9 with call-outs.

   iii. *Please change Note 3 to "all disturbed areas will be permanently vegetated".*

   Response: Done – Sheet 9. Note 3 has been adjusted to state that all disturbed areas will be permanently vegetated. In addition, note 7 has been added to refer to Sheet 8 for more information regarding planting/vegetation plans.

   iv. *Add a "Note 4" to specify whether both pumping wells will remain or whether they will be properly abandoned.*

   Response: Done – Sheet 9. *Note 4 has been added stating "All remaining pumping wells will be properly abandoned in accordance with state guidelines."*

   v. *Please include all non-jurisdictional wetlands that will be affected and how they will be reclaimed.*

   Response: Done. All non-jurisdictional wetlands are shown on the Sheet 9. All areas, including non-jurisdictional wetlands, will be reclaimed in accordance with Reclamation Plan Sheets 8 and 9.

   vi. *Please state whether the berm will remain after reclamation.*

   Response: Safety berms will be removed after reclamation. Note 5 on Sheet 9 states that safety berms will be removed after reclamation.

vii. *Add a grass/tree symbol to the areas being vegetated. Please identify what type of vegetation will be used and include a schedule indicating planting, active growing season, stable, and mature growth.*

Response: Symbology has been adjusted on Sheet 9 to reflect that the mining area will be restored to a vegetated state.

2. ***Soil Amendment Plan Comments by: Surface Mining Unit and James L. Kennedy, Ph.D., P.G***

a. *The Soil Amendment Plan should not be a separate document. Please add this information to the Reclamation Plan.*

Response: Done – Sheet 8. The Soil Amendment Plan has been incorporated into the Reclamation Plan.

b. *On Page 1 in Paragraph 4 Item 1: It is said that soil borings for conformation (sic) of the presence or absence of consolidated black sands will be drilled on a 250-foot (ft) by 250-ft grid. Each grid will be 250 ft x 250 ft = 62,500 ft^2, or 62,500 ft^2/43,560 ft^2/acre = 1.43 acre. At least two samples should be collected from each 250 ft x 250 ft grid for a sample spacing of 1 sample for each 0.715 acre. As an alternative, the proposed mine site can be divided into a 200 ft x 200 ft grid and soil samples will be taken in the middle of each grid. This would be a sample spacing of 200 ft x 200 ft = 40,000 ft^2, or 40,000 ft^2/43,560 ft^2/acre = 0.92 acre per sample.*

Response: The plan has been amended to implement the second option. It now states that the site will be divided into a 200 ft x 200 ft grid and that one soil sample will be taken in the middle of each grid (Sheet 8).

c. *On Page 2 in Paragraph 1: The paragraph says that a soil amendment layer of 10 percent bentonite will be applied in a layer approximately 3 feet thick. Data Table 6 of the report of Laboratory Testing Data at Twin Pines Mine prepared by TTL on 26 November 2019 shows that a 10 percent bentonite to sand ratio will have a hydraulic conductivity of 10^{-7} centimeters per second (cm/s). Paragraph 4 of the Subsurface Continuity of Humate-Bearing Sands in the Surficial Aquifer, Trail Ridge, Georgia in Supporting Document A to the 25 January 2021 submittal say the hydraulic conductivity of the consolidated black sand at the proposed mine site was 3.4×10^{-7} to 2.7×10^{-8} cm/s. Table 6 of the report of Laboratory Testing Data at Twin Pines Mine shows that a hydraulic conductivity of 10^{-8} cm/s can be achieved with a 12.5 percent bentonite to sand ratio and therefore the bentonite to sand ratio in the Soil Amendment Plan needs to be changed to 12.5 percent.*

Response: Done – Sheet 8. Bentonite-to-sand ratio in the Soil Amendment Plan has been changed to 12.5 percent.

d. *On Page 2 in Paragraph 2 Bullet 3: According to Page 5 Paragraph 3 of the 12 June 2020 Application for Industrial Groundwater Withdrawal Permit Twin Pines Minerals, LLC Saunders Demonstration Mine prepared by TTL, routine dewatering of the mine* *excavation is not expected except under conditions specified in the permit application. Paragraph 3 further says that excavation will be continuous, during wet and dry conditions. The top of Page 2 of the Monitoring and Adaptive Management Plan prepared by TTL on 13 November 2020 says that the water table at the proposed mine site is very shallow, with water depths of only a few feet. Page 5 Paragraph 3 of the Soil Amendment Plan says that the pit will be backfilled to a level approximately 10 feet below the original land surface and that the blended sand/bentonite material will be placed at a level/interval of 7 to 10 feet below the original land surface. Based on what was said in the Adaptive Management Plan it would be expected that the level/interval of 7 to 10 feet below the original land surface would be below the water table in the un-dewatered mine excavation. The soil amendment plan needs to explain how the blended sand/bentonite material will be placed at a level/interval of 7 to 10 feet below the original land surface below the water table in the mine excavation in a manner that does not allow the bentonite to separate from the sand, or explain how the mine excavation will temporarily be dewatered to allow placement of the blended sand/bentonite material.*

Response: Because the sand/bentonite mixture is very cohesive, it can be cast into the open pit whether it is wet or dry, without separating. Because backfilling will occur within 500 feet of the leading edge of the drag line, groundwater will not have time to completely fill the pit, and most water will be absorbed by the tailings material, which will be very dry and absorbent (Sheet 8 – Section 1.1., 5th Bullet).

e. *The Soil Amendment Plan has no provision for monitoring of groundwater levels in the reclaimed mine. The Soil Amendment Plan must propose a groundwater level monitoring plan such as that shown by the proposed piezometer locations shown on Figure 9 in the Monitoring and Adaptive Management Plan prepared by TTL on 13 November 2020. Monitoring of groundwater levels must be conducted monthly until groundwater levels are within one foot of groundwater levels shown on Figure 3 of the Monitoring and Adaptive Management Plan. After groundwater levels reach within one foot of groundwater levels shown on Figure 3 groundwater levels may be measured once every six months. The Soil Amendment Plan must include a contingent plan in case groundwater levels in the reclaimed mine are not restored to within one foot of groundwater levels shown on Figure 3. Such a plan may involve installation of a low hydraulic conductivity layer by the injection of bentonite slurry to a level/interval of 7 to 10 feet below the original land surface in closely spaced borings. Other engineered solutions may be feasible. The contingent plan must not be implemented without prior approval from the Georgia Environmental Protection Division.*

Response: The groundwater-level monitoring plan is addressed on Sheet 10, and a reference has been added to the Soil Amendment Plan.

Regarding restoration objectives, TPM respectfully requests that EPD consider an alternative to the target requiring groundwater levels be restored to within a foot of the level measured on a specific date in history. Any such target would be arbitrary and difficult to achieve because groundwater levels vary naturally by more than a foot over both space and time. As an alternative, TPM suggests requiring groundwater levels to be restored to a groundwater “normal” that accounts for natural seasonal and climatic changes. The basis for this proposal is set forth in Exhibit D.

3. *Exhibit E. Monitoring and Adaptive Management Plan Comments by: Surface Mining Unit*

a. *Exhibit E needs to be placed in the MLUP instead of a separate document.*

Response: Done. It is now Sheets 10 through 12 of the MLUP.

b. *Rename to Groundwater and Surficial Water Monitoring Plan.*

Response: Done. It is now Sheets 10 through 12 of the MLUP and titled Groundwater and Surface Water Monitoring Plan.

c. *The report must be stamped by a GA Registered PG.*

Response: Done.

d. *Monitoring of groundwater levels must be conducted monthly until groundwater levels are within one foot of groundwater levels shown on Figure 3. After groundwater levels reach within one foot of groundwater levels shown on Figure 3 groundwater levels may be measured once every six months.*

Response: See response to comment 2e.

e. *Please add a contingent(cy) plan in case groundwater levels in the reclaimed mine are not restored to within one foot of groundwater levels shown on Figure 3. Such a plan may involve installation of a low hydraulic conductivity layer by the injection of bentonite slurry to a level/interval of 7 to 10 feet below the original land surface in closely spaced borings. Other engineered solutions may be feasible. The contingent plan must not be implemented without prior approval from the Georgia Environmental Protection Division.*

Response: An adaptive management plan is set forth on Sheet 11 - Part 2.4 and 2.5 of Groundwater and Surficial Water Monitoring Plan. See response to comment 2e regarding the target groundwater level.

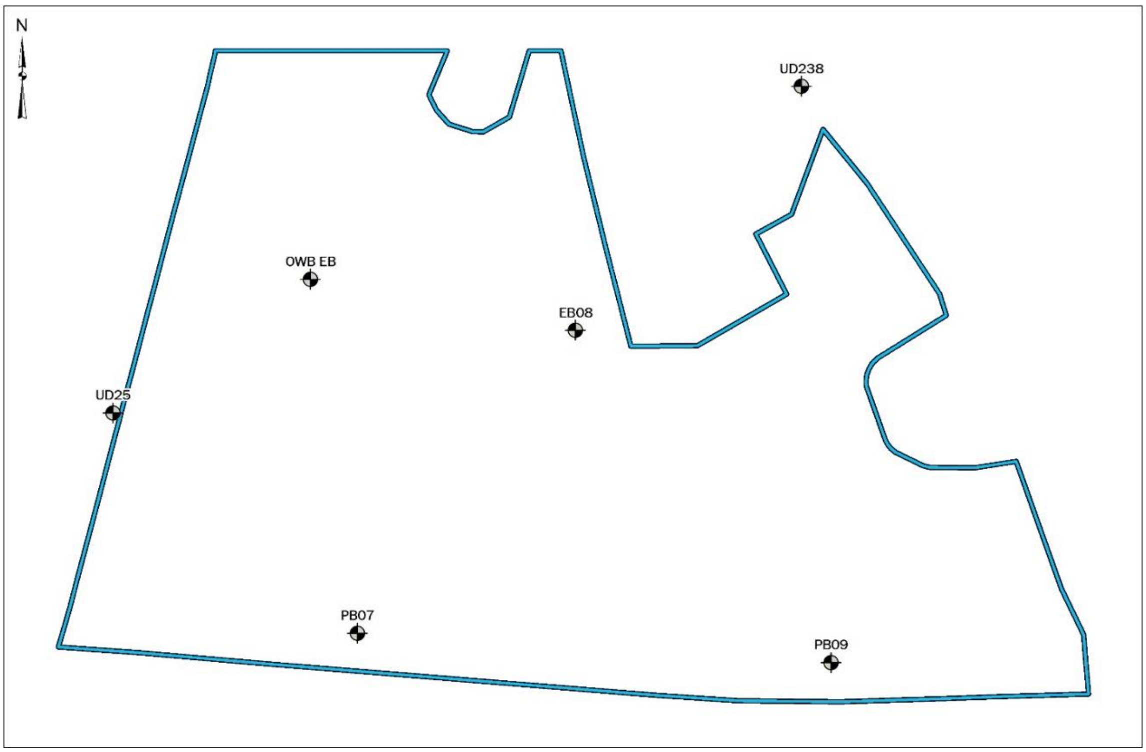
f. *In Section 2.0, 2nd Paragraph, the text states the ridge forms a hydrologic divide. Please clarify if it is a surficial and/or groundwater divide.*

Response: The paragraph has been removed from the revised Groundwater and Surface Water Monitoring Plan Sheet. However, the ridge forms both a topographic and hydrologic (groundwater) divide between the Okefenokee swamplands to the west and the Saint Marys River to the east.

g. *In Section 2.0, 3rd Paragraph, give the approximate depth of the clay layer.*

Response: The paragraph has been removed from the revised Groundwater and Surface Water Monitoring Plan Sheet. However, near the proposed mine footprint, the top of Hawthorn Group was encountered at the following locations and depths:

Boring ID	Depth to the Top of the Hawthorn Group (feet below ground surface)	Elevation of the Top of the Hawthorn Group (feet above mean sea level)
EB08	121.00	52.68
OWB EB	122.00	50.69
UD25	100.00	65.49
UD238	112.50	55.81
PB07	111.00	62.50
PB09	110.00	63.25



h. *In Section 3.1.2., 2nd paragraph, give the estimated depths and screen intervals of the shallow and deep piezometers. In the 3rd paragraph – Fig 11 shows the cone of depression to be about 3600 ft long, not 2000.*

Response: The estimated depths of the screen intervals of the shallow (10-50 feet bgs) and deep (70-80 feet bgs) piezometers are provided on Sheet 10 Section 1.1.2 (a) and (b) of the MLUP. The sentence and figure in the referenced "3rd paragraph - Fig 11" have been removed.

i. *In Section 3.1.2.b), 1st paragraph, give a brief explanation of why the depths of 50 and 80 feet were chosen.*

Response: Done –Sheet 10 Section 1.1.2 (a) - Twenty-four (24) piezometers will be installed within the footprint of the mine. Eighteen (18) piezometers will be installed to depths of about 50 feet bgs and used to monitor water quality across the maximum vertical extent of the proposed mine. Six (6) piezometers will be installed to depths of about 80 feet bgs in order to monitor water levels and water quality of the Surficial Aquifer below the maximum mining depth.

j. *In Section 3.1.2.c), 3rd bullet, add each piezometer that will be resurveyed after installation and before water level measurements are collected.*

Response: Done – Sheet 10 Section 1.1.2 (c) – a bullet has been added stating "The replacement piezometers will be resurveyed after installation and before water level measurements are collected".

k. *In Section 4.5, add notify the Director "in writing" within 30 days.*

Response: Done – Sheet 10 Section 2.5. The language has been added that states "If the conditions described in Part 2.4 are not achieved, TPM will notify the Director within 30 days. Such notice will include the monitoring data along with any relevant information. "

l. *In Figure 2, add a note stating that Twin Pines does not have access to TIAA property.*

Response: Done – Sheet 11

m. *In Figure 9, PZs-15, 16, 28, 27, and 26 are not shown.*

Response: Groundwater-level data will be monitored in the 68 existing on-site piezometers plus the 24 proposed (MPZ) piezometers. These monitoring points are shown on Sheet 11 and listed on Sheet 12.

n. *In Figure 11, please explain why asymmetrical was used. How was cone of depression calculated? Is this figure needed?*

Response: TPM agrees the figure is not needed. It has been deleted.

o. *In Figure 12, please explain why 51 ft depth was chosen.*

Response: The eighteen (18) piezometers will be installed to depths of about 50 feet bgs and used to monitor water quality across the maximum vertical extent of the proposed mine. The extra foot depicted on the typical piezometer construction detail accounts for a one-foot filter sand sump beneath the bottom of the piezometer. The extra one-foot filter sand sump beneath the bottom of the piezometer has been removed (Sheet 12).

p. *In Figure 13, please explain why 81 ft depth was chosen for the figure. Please identify at what depth the clay layer is located. Please add a cross-section to show mining area, shallow/deep piezometers, and clay layer.*

Response: Six (6) piezometers will be installed to depths of about 80 feet bgs in order to monitor water levels and water quality of the Surficial Aquifer below the maximum mining depth. The extra foot depicted on the typical piezometer construction detail accounts for a one-foot filter sand sump beneath the bottom of the piezometer. The extra one-foot filter sand sump beneath the bottom of the piezometer has been removed

(Sheet 12). A cross-section depicting the shallow/deep piezometers and clay layer is provided on Sheet 12.

4. *Provisions Check List and Explanations for Protection of the Environment and Resources of the State Comments by: Surface Mining Unit*

a. *Explanations*

i. *Please note that the Surface Mining Rules Section 391-3-3-.05(1) requests that the Mining Land Use Plan include provisions for protection of the environment and resources of the State. The checklist that was provided to Twin Pines, was taken from GEPA but meant to be used as a guidance for Twin Pines to follow and make their own. EPD is not asking Twin Pines to follow GEPA regulations. The provisions checklist will be an addendum to the Surface Mining Land Use Plan (MLUP) and used during public meetings as an outline of the affects the Twin Pines project may have on the surrounding environment and resources of the State.*

Response: Thank you for your clarification. Text referring to GEPA has been deleted.

ii. *Wetlands- Give a brief description of how the non-jurisdictional wetlands will be temporarily affected and then reclaimed.*

Response: Additional detail has been added to this checklist explanation, and on Sheet 9 of the MLUP.

iii. *Flood Plain/River Corridor- Cite the source that was used to determine the claim.*

Response: Flood Insurance Rate Map (FIRM) Panel numbers have been referenced. Georgia Rule 391-3-16-.04(2)(m) (Criteria for River Corridor Protection) has also been referenced.

iv. *Water Supply - State how the proposed withdrawal is compared to the production capacity of the Floridan Aquifer. Also provide the distance to the nearest known supply well, public or private, completed in the Floridan Aquifer. Will withdrawal from the Floridan Aquifer create a cone of depression that may impact nearby watersheds? If so, this data needs to be provided or pointed to within the MLUP.*

Response: TPM conducted an analysis of the effects of withdrawal from the Floridan Aquifer. This analysis is documented in Attachment A of this document. A summary of the results of the analysis is also provided in the checklist explanations document.

v. *Water Resources- Please provide an explanation of any potential water quality impacts as a result of the groundwater withdrawal from the Upper Floridan Aquifer.*

Response: Additional detail regarding potential water quality impacts as a result of groundwater withdrawal from the Upper Floridan Aquifer have been added to the checklist explanations document.

vi. *Groundwater Recharge- No comment.*

vii. *Stormwater- Please state the name of the receiving stream from the discharge. Provide details of a contingency plan if discharge is greater than pre-mining conditions. Briefly describe erosion/sediment controls at discharge location(s).*

Response: The names of the receiving streams have been added. Additional detail regarding contingency plans and erosion/sediment controls at discharge locations has been added.

viii. *Wastewater- Briefly state how the water will be treated and how the effluent will be monitored for permit compliance.*

Response: Additional detail regarding how water will be treated and the effluent monitored has been added.

ix. *Air Quality- Briefly describe how Twin Pines will minimize particulate/opacity emissions. This area is for the mine boundary as well as the plant.*

Response: Additional detail regarding how TPM will minimize particulate/opacity emissions has been added.

x. *Solid Wastes- The first sentence indicates that process solid waste may be generated but will stay on-site; please clarify what Twin Pines will do with processed solid waste. Second sentence- Please state how the office-related waste will be properly transported and disposed. Can you describe how the land clearing will be handled?*

Response: Clarification of the handling of both process and office-related waste has been added. A description of how land clearing will be handled has been added.

xi. *Soil/Stability/Erodibility- Please describe how the site will reduce the potential for sediment-laden soils to leave the site. Briefly describe the berm during mining activities and the deposition of the berm following reclamation.*

Response: Additional detail has been added regarding how TPM will reduce the potential for sediment-laden soils to leave the site. Additional information regarding the function of the berm has been added.

xii. *Protected Mountains- No comment.*

xiii. *Protected Species- Briefly describe what protected species may be/are present in the area, what surveys were conducted, and if any protected species were found in the proposed mine footprint. Include some of the information that you provided in Exhibit D.*

Response: Lists of protected species that may be present in the area were added, along with the determination as to whether they were identified in the proposed mine footprint.

xiv. *Critical Habitats- Rephrase to include that the nearest critical habitat identified is the Okefenokee NWR and it's 2.9 miles away.*

Response: This section has been rephrased to indicate that the nearest critical habitat identified is the Okefenokee NWR and it is 2.9 miles away. Also, additional detail has been added regarding the results of the groundwater model submitted to EPD, which shows a negligible decrease of the water table at the Refuge boundary.

xv. *Historical- Please refer to the Cultural Resources assessment as Exhibit C of the Surface Mining Land Use Plan.*

Response: The Cultural Resources assessment has been referenced as Exhibit C of the MLUP.

xvi. *Archaeological - Please state if there are any known historical/cultural/ archaeological resources on the mine property or on the adjacent properties. Please explain what procedures will be followed if these resources are found while mining.*

Response: Additional detail regarding the studies conducted and the resources identified has been added. Procedures that will be followed if archaeological resources are found while mining have been added.

xvii. *Parks/Recreation- Please explain "negligible" affects. If there is going to be an affect, please provide a brief explanation and cite applicable sources.*

Response: An explanation of "negligible" effects has been added.

xviii. *Energy Supplies- Please state who will run the necessary power lines to supply the operation and state whether the power draw will affect surrounding businesses and/or homeowners or not. If an affect is expected, explain what the affect will be. Please include average projected energy use to verify statement (equivalent to an average household power usage).*

Response: The explanation has been revised to identify who will be providing the power supply, locations of substations, and an estimate of power usage by TPM.

xix. *Beaches- No Comment*

xx. *Dunes- No Comment*

xxi. *Shoreline- No Comment*

xxii. *Coastal Marshland- No Comment*

xxiii. *Forest Land- Please provide more information on what types of trees will be planted during reclamation.*

Response: Additional information regarding the types of vegetation that will be planted has been added to this checklist explanation and on Sheet 9 of the MLUP.

xxiv. *Barrier Island- No Comment*

xxv. *Aquatic Life/Trout Streams- Please state that the NPDES discharge limits are* *designed to be protective of aquatic life and describe how the sampling will ensure water discharge permit compliance.*

Response: The explanation has been revised to state that NPDES discharge limits are designed to be protective of aquatic life. Additional detail regarding sampling parameters and frequency has been added.

5. ***Technical Response to Review Comments Provided by State Geologist & Supporting Documents Comments by: James L. Kennedy, Ph.D., P.G.***

Response: TPM responses to comments 5a through 5h will be submitted under separate cover upon completion of our revised groundwater model and additional laboratory leaching test.

6. ***Subsurface Continuity of Humate-Bearing Sands in the Surficial Aquifer, Trail Ridge, Georgia Comments by: James L. Kennedy, Ph.D., P.G.***

Response: TPM responses to comments 6a through 6c will be submitted under separate cover upon completion of our revised groundwater model.

7. ***Groundwater Withdrawal Permitting Application Comments by: Bill Frechette and John Ariail***

a. *Twin Pines submitted a revised application dated 12-09-2020, requesting a new groundwater withdrawal permit to withdraw up to 1.440 mgd from two wells in the Floridan aquifer.*

Response: Agreed – no response required.

b. *In Section 6 – page 14 of the application and Table 2 – page 9 of attachment B ("An evaluation of drawdown from Floridan wells") lists three scenarios for the total drawdown of the Floridan aquifer at the edge of the Okefenokee National Wildlife Refuge (ONWR), based on pumping two wells at 500 gpm for 4 years.*

"The maximum drawdown of the Floridan Aquifer at the edge of the ONWR is 3.8 ft in the Base Case Scenario, 13.2 ft for the Maximum-Drawdown Scenario, and 1.3 feet for the Minimum-Drawdown Scenario."

The application does not quantify the impact to the Surficial aquifer at the edge of the ONWR, as a result of the Floridan aquifer "Maximum-Drawdown Scenario" listed above. Please provide further analysis / detailed modeling to quantify the surficial aquifer drawdown at the edge of the ONWR, based on the Floridan aquifer drawdown numbers provided in the application. This may require a more detailed modeling of the drawdown in the Floridan aquifer, and its associated impact to the Surficial aquifer.

Response: TPM performed additional analysis to quantify the impact to the surficial aquifer at the edge of the ONWR as a result of the Floridan Aquifer "Maximum-Drawdown Scenario." The results of the analysis show that the drawdown of the Surficial Aquifer at the edge of the ONWR is essentially zero. A detailed description of the analysis performed, entitled, "Analysis of Impacts to Surficial Aquifer" is provided in Attachment B of this document.

c. *Consider possible range of hydraulic conductivity for the aquitard in this analysis. Provide supporting evidence of this range by either literature review or field investigation.*

Response: TPM maintains that the hydraulic conductivity value used in the analysis is appropriate. Supporting documentation is provided in Attachment B.

As noted above, a complete revised Surface Mining Land Use Plan and Provisions Checklist for Protection of the Environment and Resources of the State are being submitted to the EPD. Attached to this letter are supporting documents A and B which provided detailed responses to comments 4(a)(iv) and 7(b) and 7(c). Responses to comments 5 and 6 above will be submitted in the near future.

Please let us know if you have any further questions or comments.

Sincerely,
TTL, Inc.

Sheryle G. Reeves
James R. Smith

Sheryle G. Reeves, P.E.
Principal Engineer

James R. Smith, P.G.
Principal Geologist

cc: Mark Fowler, Twin Pines Minerals, LLC

Attachments: A – Supporting Documentation for Response to Comment 4(a)(iv)
B – Supporting Documentation for Responses to Comments 7(a) and 7(b)

ATTACHMENT A
Supporting Documentation for Response to Comment 4(a)(iv)

Supporting Documentation for Response to Comment 4(a)(iv)

Twin Pines Minerals, LLC (TPM) has conducted an analysis to evaluate the potential impacts to water supply watersheds in the vicinity of the proposed Saunders Demonstration Mine due to the pumping of process water from the Upper Floridan Aquifer.

Based on the well inventory prepared for the project, there are no public water supply wells in the area. The nearest known public water supply well completed in the Floridan Aquifer is located in Folkston, Georgia, approximately 22 miles northeast of the proposed Saunders Demonstration Mine Site. To the best of our knowledge, the nearest known private water supply well completed in the Floridan Aquifer is located at the Martin Marietta Materials – St Marys Sand Company, approximately 11 miles southeast of the proposed Saunders Demonstration Mine Site. Based on our review of readily available published information, there are four permitted water supply wells installed within the Floridan Aquifer in Charlton County, Georgia (see Table 1).

Three of the four water supply wells installed within the Floridan Aquifer are within the St Marys River Basin and one well is within the Satilla River Basin (Table 1). To compare the production capacity of Floridan Aquifer to the proposed withdrawal at the proposed Saunders Demonstration Mine Site, we evaluated the approved permitted withdrawal limits of the four permitted water supply wells to the proposed withdrawal rate at the mine site. The proposed withdrawal rate at the proposed mine site (1.44 million gallons per day (MGD)) is generally consistent with the permitted monthly withdrawal limit for the City of Folkston (1.50 MGD) and within the production capacity of the Floridan Aquifer.

The Theis (1935) solution is used to predict well drawdowns (s) caused by pumping in wells FPW-01 and FPW-02 over the 4-year life of the mine and determine the potential impact on nearby river basins. The Theis (1935) equation is given by

$$s(r,t) = \frac{Q}{4\pi T} W(u) \,, \qquad (1)$$

where Q is the pumping rate (500 gpm or 96,250 ft^3/day for each well), r is the radial distance from the well, T is the aquifer transmissivity, and $W(u)$ is the Theis well function, given by the exponential integral

$$W(u) = \int_u^\infty \frac{e^{-y}}{y} dy \ . \qquad (2)$$

The variable u is

$$u = \frac{r\,S}{4Tt}\,, \tag{3}$$

where S is the aquifer storage coefficient and t is time. The Theis solution assumes that the aquifer is infinite, confined, and homogeneous; that equipotentials are vertical; and that the well diameter is negligible. The total drawdown from both wells in the aquifer is determined by linearly superimposing (summing) the contributions from each well.

A MATLAB code was developed to predict the drawdown (Attachment 1). The MATLAB code predicts the spatial drawdown due to pumping at several wells at a specified time. The code allows the user to define the number of wells, aquifer properties (T and S), and a pumping schedule for each well. MATLAB commands used for this code are shown in Attachment 1. The code requires the text file Welldat.dat (Attachment 1), which includes the X-location, Y-location, time that pumping starts, time that pumping ends, and pumping rate for each well.

The MATLAB code requires an estimate of T and S for the Floridan Aquifer. Williams and Kuniansky (2016) report T and S values for 11 wells in the upper Floridan Aquifer. One well had an anomalously low T value and was excluded from our analysis. The T and S values for the remaining 10 wells were averaged to define the values of *T and S used here* (Table 2). The predicted drawdown at the proposed production wells after 4 years of pumping at the TPM site is shown in Figure 1. These results indicate that the basin north of the St. Marys River Basin will see drawdown of less than 1 foot due to TPM pumping, the basins south and west of the St. Marys River Basin will have drawdown between 1 foot and 2 feet, and the basin east of the St. Marys River Basin will show drawdown of slightly over 2 feet.

It is important to recognize that the results presented here represent conservative values. The drawdown was estimated using the Theis (1935) solution. This solution neglects leakage from the overlying Hawthorn group. Leakage, or downward flow, from the Hawthorn will lead to less drawdown in the Floridan Aquifer. We attempted to use the Hantush and Jacob (1955) solution for leaky aquifers to predict the drawdown, but the solution is prone to numerical errors given the hydraulic properties germane to the Floridan Aquifer and the distances to the edge of the St. Mary's River Basin and yields spurious results.

References Cited

Hantush, M.S. and C.E. Jacob, 1955, Non-steady radial flow in an infinite leaky aquifer: American Geophysical Union Transactions., vol. 36, pp. 95-100.

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage: Transactions of the American Geophysical Union, 16th Annual Meeting, p. 519-524.

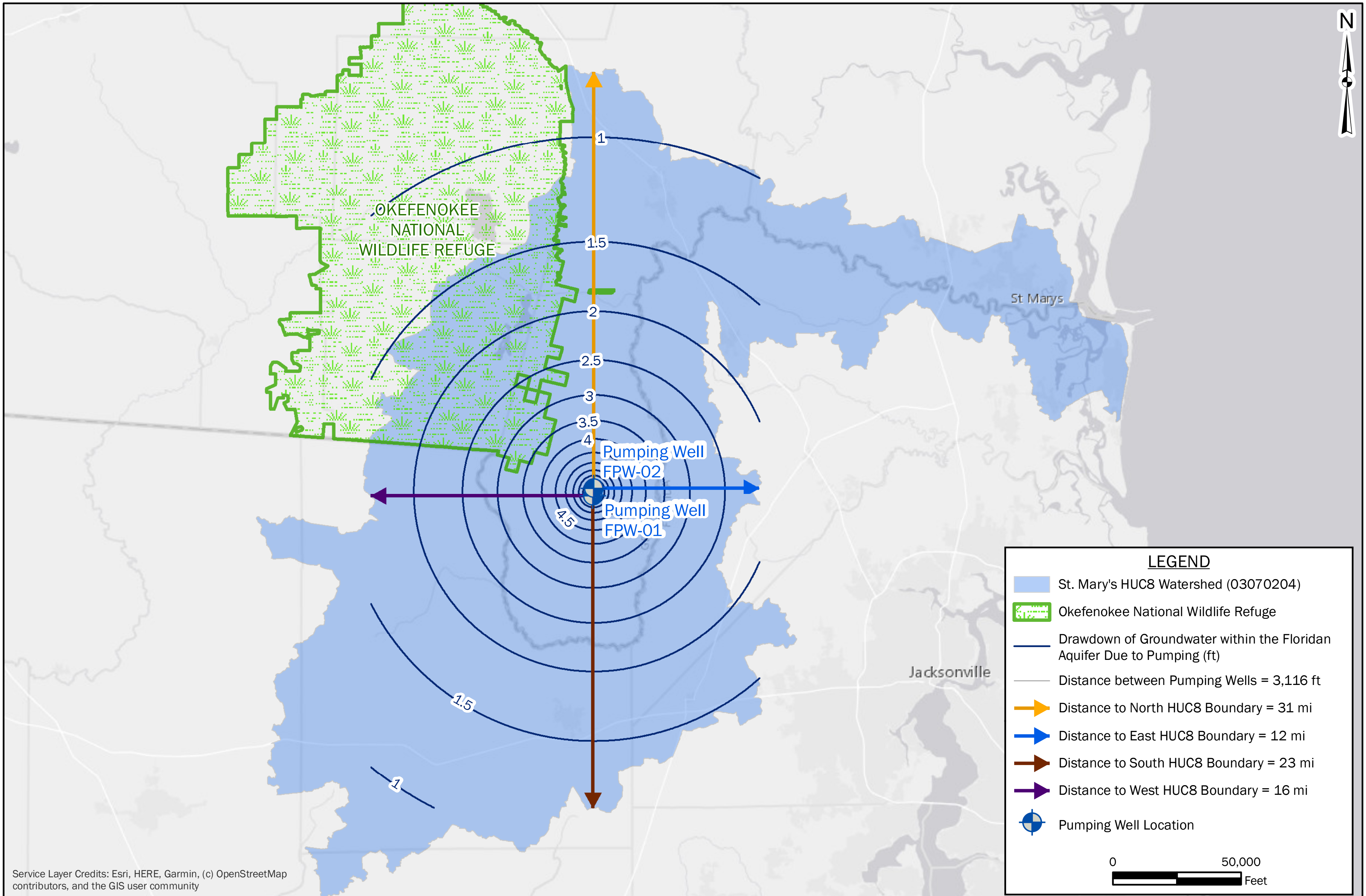
Williams, L.J., and Kuniansky, E.L., April 2015 (Revised March 2016), Revised Hydrogeologic Framework of the Floridan Aquifer System in Florida and Parts of Georgia, Alabama, and South Carolina: U.S.G.S, Professional Paper 1807, Version 1.

Table 1. Nearest known production wells in the Floridan Aquifer.

River Basin	Groundwater Withdrawal Permit Holder	Groundwater Withdrawal Permit Number	County	Aquifer(s) - Source	Approximate Distance from the Proposed Saunders Demonstration Mine (Miles/Direction)	Permit Limit Yearly Average (Million Gallons/Day)	Permit Limit Monthly Average (Million Gallons/Day)
Saint Marys	Folkston, City of	024-0001	Charlton	Floridan	22/NE	1.250	1.500
Saint Marys	Homeland, City of	024-0005	Charlton	Floridan	23/NE	0.150	0.150
Saint Marys	Martin Marietta Materials - St Mary's Sand Company	024-0006	Charlton	Floridan	11/SE	0.200	0.200
Satilla	Southern Ionics Minerals - Mission Mine	024-0004	Charlton	Floridan	36/NE	0.504	0.504
River Basin	**Groundwater Withdrawal Permit Holder**	**Groundwater Withdrawal Permit Number**	**County**	**Aquifer(s) - Source**	**Approximate Distance from the Proposed Saunders Demonstration Mine (Miles/Direction)**	**Proposed Pumping Rate (Million Gallons/Day)**	
Saint Marys	Proposed Twin Pines Minerals LLC Saunders Demonstration Mine	—	Charlton	Floridan	---	1.44	

Table 2. Hydraulic properties for the upper Floridan Aquifer in north Florida (Williams and Kuniansky, 2016).

Well ID	Transmissivity (ft^2/day)	Storage Coefficient (dimensionless)	Hydraulic Diffusivity (ft^2/day)
IWSD-TW*	36000	1.00E-02	3.60E+06
ROMP14	6570	9.90E-04	6.64E+06
ROMP39	12000	1.60E-04	7.50E+07
36Q330	40000	2.00E-04	2.00E+08
ROMP43	13000	2.00E-05	6.50E+08
OSF-97	15500	2.20E-05	7.05E+08
ROMP45.5	26000	3.00E-05	8.67E+08
I75-TW	16000	1.70E-05	9.41E+08
M505	9880	7.30E-06	1.35E+09
BICY-TW**	11000	5.00E-06	2.20E+09
Average	**18595**	**1.15E-03**	



TTL

FIGURE 1: FLORIDAN AQUIFER PUMPING WELL DRAWDOWN MAP

TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE (ID NO. 2073)

ST. GEORGE, CHARLTON COUNTY, GEORGIA

BASEMAP: ESRI World Light Gray Canvas Base (See Service Layer Credits).

DRAWN BY: DEK
CHECKED BY: RMH
DRAWING DATE: 6/5/2021
REVISION DATE: N/A
TTL JOB NO.: 000180200804.00
APPROX. SCALE: 1 in = 50,000 ft

Attachment 1

MATLAB Code for Estimating Drawdown, MATLAB Input command, and MATLAB Input Data File

MATLAB File:

```
function hh=Theis_Superposition_N_wells(nx,ny,delx,dely,xst,yst,Nwell,T,t,S)
%nx=number of points to evaluate in the x-direction
%ny=number of points to evaluate in the y-direction
%delx = Distance between points in the x-direction
%dely = Distance between points in the y-direction
%xst = starting x-coordinate of plot
%yst = starting y-coordinate of plot
%Nwell= number of wells
%welldat= a predefined array (in file 'welldat.dat' of length Nwell with
%            x,y,start time,end time,Q data for each well
%T = K*B = Transmissivity
%t = time to evaluate pressures
%S = Storage Coefficeint (dimensionless)
%h(k,5) = Drawdown
%h3(i,j) = 2D array of drawdowns for plotting
welldat=dlmread('welldat.dat');
for i=1:nx+1
    %define x location
    x=(i-1)*delx+xst;
    for j=1:ny+1
        %define y location
        y=(j-1)*dely+yst;
        %define global index for output
        k=(i-1)*(nx+1)+j;
        %calculate the drawdown for each well
        for m=1:Nwell
            if (welldat(m,3)<=t)&&(welldat(m,4)>=t)
                %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
                %calculate well function
                u=S*(r)^2/(4*T*(t-welldat(m,3)));
                %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u);
            elseif (welldat(m,4)<=t)
                %calculate radial distance from point x,y to the well
                r=((x-welldat(m,1))^2+(y-welldat(m,2))^2)^0.5;
                %calculate well function for pumping
                u1=S*(r)^2/(4*T*(t-welldat(m,3)));
                u2=S*(r)^2/(4*T*(t-welldat(m,4)));
                %calculate drawdown
                hw(m)=(welldat(m,5)/(4*3.14151*T))*expint(u1)-
(welldat(m,5)/(4*3.14151*T))*expint(u2);
            else
                hw(m)=0;
            end
        end
        %superimpose drawdowns
        h(k)=sum(hw);
        %setup output array
        hh(j,i)=h(k); %build array
        h3(j,i)=h(k); %build array for plotting
    end
end
%define x-coordinate vector for plot151
for i=1:nx+1
    xx(i)=(i-1)*delx+xst;
end
%define y-coordinate vector for plot
for j=1:ny+1
    yy(j)=(j-1)*dely+yst;
```

```
end
%contour plot drawdowns
figure;
[C,h]=contour(xx,yy,h3);
%[C,h]=contour(h3);
clabel(C,h);
end
```

MATLAB Command:

Theis_Superposition_N_wells(303,575,500,500,591200,67453,2,18595,1460,1.15e-3)

MATLAB Datafile: Welldat.dat

677916.21	189234.47	0	1460	96250
678226.53	192335.26	0	1460	96250

ATTACHMENT B
Supporting Documentation for Response to Comments 7(b) and 7(c)

Supporting Documentation for Response to Comments 7(b) and 7(c)

Twin Pines Minerals, LLC (TPM) has conducted an analysis to evaluate the potential impacts to the Surficial Aquifer at the boundary of the Okefenokee National Wildlife Refuge due to the pumping of process water from the Upper Floridan Aquifer. This document specifically provides responses to the Georgia Environmental Protection Division's (EPD's) Permit Coordination review comments 7b and 7c.

Comment 7 b:

In Section 6 – page 14 of the application and Table 2 – page 9 of attachment B ("An evaluation of drawdown from Floridan wells") lists three scenarios for the total drawdown of the Floridan aquifer at the edge of the Okefenokee National Wildlife Refuge (ONWR), based on pumping two wells at 500 gpm for 4 years. "The maximum drawdown of the Floridan Aquifer at the edge of the ONWR is 3.8 ft in the Base Case Scenario, 13.2 ft for the Maximum-Drawdown Scenario, and 1.3 feet for the Minimum-Drawdown Scenario."

The application does not quantify the impact to the Surficial aquifer at the edge of the ONWR, as a result of the Floridan aquifer "Maximum-Drawdown Scenario" listed above. Please provide further analysis / detailed modeling to quantify the surficial aquifer drawdown at the edge of the ONWR, based on the Floridan aquifer drawdown numbers provided in the application. This may require a more detailed modeling of the drawdown in the Floridan aquifer, and its associated impact to the Surficial aquifer.

<u>Response to Comment 7 b:</u>

Dr. James Kennedy, in a meeting on April 29 2021, directed TPM to use an approach developed by Hantush (1967) to evaluate drawdown in the surficial aquifer caused by leakage through the Hawthorn Group due to TPM's proposed pumping in the Floridan Aquifer. Dr. Kennedy supplied TPM with a spreadsheet for these calculations. The spreadsheet implements Equation 26 of Hantush (1967), which is a pseudo steady-state solution for the drawdown in an upper aquifer separated by an aquitard from a lower aquifer that is pumped. Unfortunately, the Equation 26 of Hantush (1967) is an approximation which produces negative drawdowns (water-level increases) in the Surficial Aquifer using the parameters appropriate to hydraulic conditions found at the TPM site. To complete the analysis directed by Dr. Kennedy, we modified his spreadsheet to solve the steady-state form of Equations 45 and 46 of Hantush (1967) (Attachment 1). These equations solve for the steady-state drawdown in an un-pumped upper and a pumped lower aquifer separated by an aquitard. These solutions assume that the aquifer is circular with no drawdown at the boundary, and that the well is pumped at a fixed pumping rate for an infinite period of time.

The hydraulic properties used for the Floridan Aquifer are those used by Holt and Tanner (2020) for their Minimum, Base Case, and Maximum Drawdown Scenarios. The hydraulic conductivity of the Hawthorn Group was assumed to be 10^{-4} ft/day (e.g., Williams and Kuniansky, 2015) and the specific storage for the Hawthorn was assumed to be 10^{-4} 1/ft, which is typical for clay units. Instead of pumping 500 gpm from two wells, we assumed that all pumping was occurring in a single well that is closest to the ONWR with a pumping rate of 1,000 gpm. This represents a conservative case.

Initially, we determined the effective radius defined by Hantush (1967) and used in the spreadsheet provided by Dr. Kennedy. This effective radius ranged from 5,728 ft to 5,731 ft. It should be noted that the distance from the nearest TPM well to the edge of the ONWR is 22,304 ft. So, this model cannot be used to predict the drawdown at the edge of the ONWR, as the drawdown is 0 ft at the effective radius.

The radius of the model does not have to be defined as Hantush's effective radius; instead, it can be defined to match the distance of observed physical boundaries. Because no physical boundaries can be defined over reasonable distances in the Floridan Aquifer, we arbitrarily chose a radius of 44,608 ft, twice the distance between the boundary of the ONWR and the nearest pumping well. The results of this model are presented in Table 1, which shows the drawdown in the Surficial Aquifer and the Floridan Aquifer at the edge of the ONWR and 1 ft away from the pumping well. For the three cases considered by Holt and Tanner (2020), the drawdown in the Floridan Aquifer ranged from 9.1 to 29.8 ft at a distance of 1 ft from the pumping well and 0.6 to 1.9 ft at the edge of the ONWR. The drawdown in the Surficial Aquifer ranged from ~0.8 to 0.3 ft at a distance of 1 ft from the pumping well and ~ 0.05 to 0.15 ft at the edge of the ONWR. The predicted drawdown in the Floridan is consistent with that predicted by Holt and Tanner (2020) (their Table 2). The drawdown in the surficial aquifer is surprisingly small, considering that the model assumes that the well is pumped forever.

It is important to remember that these results reflect pumping 1,000 gpm from a single well for an infinite period of time; the drawdown in the Surficial Aquifer will be much smaller after pumping for a period of only 4 years. For models of this type, a time constant can be defined to evaluate whether or not drawdown in the unpumped aquifer remains zero (e.g., Hantush, 1960; Neuman and Witherspoon, 1969):

$$\tau_c = 0.1\frac{S_s^* b^{*2}}{K^*}$$

where S_s^* is the specific storage of the aquitard (here 10^{-4} 1/ft), b^* is the thickness of the aquitard (here 325 ft), and K^* is the hydraulic conductivity of the aquitard (here 10^{-4} ft/day). If the time for pumping is less than τ_c, then the drawdown in the unpumped aquifer is essentially zero. In our case, the duration of pumping is 1,460 days, and τ_c = 10,562.5 days; therefore, drawdown in the surficial aquifer will be essentially zero at the end of 4 years. To help put this in perspective, τ_c represents 6.3% of the time required to reach steady state in the aquitard (the Hawthorn), and the time of pumping (1,460 days) is 0.87% of the time required to reach steady state in the Hawthorn. For time periods this short, changes in the head in the Floridan Aquifer will not have time to propagate upward through the Hawthorn and reach the Surficial Aquifer.

Comment 7 c:

Consider possible range of hydraulic conductivity for the aquitard in this analysis. Provide supporting evidence of this range by either literature review or field investigation.

<u>Response to Comment 7c:</u>

We use a realistic value of 10^{-4} ft/day for the hydraulic conductivity of the Hawthorn aquitard; this value is one order of magnitude higher than that used in calibrated USGS groundwater models that include the TPM area. Supporting evidence is listed below.

Williams and Kuniansky (2015) indicate that the vertical hydraulic conductivity of the Hawthorn is small (less than 10^{-4} ft/day) when clays are present and that leakage across the Hawthorn is negligible. Calibrated groundwater models that include the proposed mine and the Okefenokee Swamp area use a vertical hydraulic conductivity of 10-5 ft/day for the Hawthorn (Payne et al., 2005; Cherry, 2015; and Cherry, 2019). In addition, samples of the Hawthorn taken at the Twin Pines Minerals, LLC site show hydraulic conductivity values of 3.66×10^{-2} ft/day, 2.63×10^{-5} ft/day, and 4.56×10^{-6} ft/day (Holt et al., 2019), consistent with the values used in calibrated groundwater models.

References Cited

Cherry, G.S., 2015, Groundwater Flow in the Brunswick/Glynn County Area, Georgia, 2000– 04: U.S. Geological Survey Scientific Investigations Report 2015–5061, 88 p.

Cherry, G.S., 2019, Simulation of Groundwater Flow in the Brunswick Area, Georgia, for 2004 and 2015, and Selected Groundwater-Management Scenarios: U.S. Geological Survey Scientific Investigations Report 2019–5035, 70 p.

Hantush, M.S., 1960, Modification of the Theory of Leaky Aquifers: Journal of Geophysical Research, v. 65, p. 3713-3725.

Hantush, M.S., 1967, Flow to Wells in Aquifers Separated by a Semipervious Layer: Journal of Geophysical Research, v. 72, p. 1709-1720.

Holt, R. M., and J.M Tanner, 2020, An Evaluation of Drawdown From Floridan Wells FPW-01 and FPW-02 at the Twin Pines Minerals, LLC Mine Site, prepared for Twin Pines Minerals LLC by TTL Incorporated, Tuscaloosa Alabama.

Holt R. M., J.M Tanner, J.R. Smith, A.C. Patton, and Z.B. Lepchitz 2019, Laboratory Testing Data at Twin Pines Mine, prepared for Twin Pines Minerals LLC by TTL Incorporated, Tuscaloosa Alabama

Neuman, S.P., and P.A. Witherspoon, 1969, Applicability of Current Theories of Flow in Leaky Aquifers, Water Resources Research, v. 5, p. 817-829.

Payne, D.F., Abu Rumman, M., and Clarke, J.S., 2005, Simulation of groundwater flow in coastal Georgia and adjacent parts of South Carolina and Florida—Predevelopment, 1980, and 2000: U.S. Geological Survey Scientific Investigations Report 2005–5089, 91 p.

Williams, L.J., and Kuniansky, E.L., 2015, Revised hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1807, 140 p., 23 pls.

Table 1. Predicted drawdown in the Surficial Aquifer and the Floridan Aquifer at the edge of the Okefenokee National Wildlife Refuge (ONWR) and 1 foot away from a proposed Twin Pines Minerals well pumping 1,000 gpm from the Floridan Aquifer. Note the well is located 22,304 ft from the ONWR boundary.

	Drawdown in the Surficial Aquifer (ft) at the edge of the ONWR	Drawdown in the Floridan Aquifer (ft) at the edge of ONWR	Drawdown in the Surficial Aquifer (ft) 1 ft from Pumping Well	Drawdown in the Floridan Aquifer (ft) 1 ft from Pumping Well
Minimum Drawdown Case	4.7E-02	0.6	8.1E-02	9.1
Base Drawdown Case	9.0E-02	1.1	1.6E-01	17.6
Maximum Drawdown Case	1.5E-01	1.9	2.7E-01	29.8

Attachment 1

Excel Spreadsheets for the Hantush (1967) Model

Surficial Aquifer Drawdown - 22,304 ft from well pumping 1,000 gpm - Minimum Drawdown Case

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units	Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
Time since beginning of pumping (t)	4.0	years	1000	0.81705280	4.66E-02	0.59
Radial distance from Lower Floridan aquifer pumping well (r)	22304	feet				
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day				
Specific Yield of surficial aquifer (S_1)	0.30000					
Transmissivity of Upper Floridan aquifer (T_2)	36,000	ft^2/day				
Stortivity of Upper Floridan aquifer (S_2)	0.01000					
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day				
Thickness of confining unit (b')	325	feet				
$\nu_1 = T_1/S_1$	5,000	ft^2/day				
$\nu_2 = T_2/S_2$	3,600,000	ft^2/day				
$\nu_v = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	9,986	ft^2/day				
$r_e = 1.5(\nu_v t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet				
$B_1 = (T_1/(K'/b')^{1/2}$	69,821	feet				
$B_2 = (T_2/(K'/b')^{1/2}$	342,053	feet				
$\beta_1 = r/B_1$	0.31944452					
$\beta_2 = r/B_2$	0.06520634					
$\beta^2 = \beta_1^2 + \beta_2^2$	0.10629667					
β	0.32603170					
$\beta\varepsilon_1 = re/B_1$	0.63888905					
$\beta\varepsilon_2 = re/B_2$	0.13041268					
$\beta\varepsilon^2 = \beta\varepsilon_1^2 + \beta\varepsilon_2^2$	0.42518668					
$\beta\varepsilon$	0.65206340					
$\ln(r_e/r)$	0.693					
$K_0(\beta)$	1.297					
$K_0(\beta\varepsilon)$	0.713471027					
$I_0(\beta\varepsilon)$	1.109154965					
$I_0(\beta)$	1					
$\delta 1 = T1/T2$	0.041666667					

Surficial Aquifer Drawdown - 22,304 ft from well pumping 1,000 gpm - Basecase

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units
Time since beginning of pumping (t)	4.0	years
Radial distance from Lower Floridan aquifer pumping well (r)	22304	feet
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day
Specific Yield of surficial aquifer (S_1)	0.30000	
Transmissivity of Upper Floridan aquifer (T_2)	18,585	ft^2/day
Stortivity of Upper Floridan aquifer (S_2)	0.00115	
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day
Thickness of confining unit (b')	325	feet
$\nu_1 = T_1/S_1$	5,000	ft^2/day
$\nu_2 = T_2/S_2$	16,160,870	ft^2/day
$\nu_\nu = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	9,997	ft^2/day
$r_e = 1.5(\nu_\nu t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet
$B_1 = (T_1/(K'/b'))^{1/2}$	69,821	feet
$B_2 = (T_2/(K'/b'))^{1/2}$	245,767	feet
$\beta_1 = r/B_1$	0.31944452	
$\beta_2 = r/B_2$	0.09075275	
$\beta^2 = \beta_1^2 + \beta_2^2$	0.11028086	
β	0.33208563	
$\beta\varepsilon_1 = re/B_1$	0.63888905	
$\beta\varepsilon_2 = re/B_2$	0.18150550	
$\beta\varepsilon^2 = \beta\varepsilon_1^2 + \beta\varepsilon_2^2$	0.44112346	
$\beta\varepsilon$	0.66417126	
$\ln(r_e/r)$	0.693	
$K_0(\beta)$	1.280	
$K_0(\beta\varepsilon)$	0.699587159	
$I_0(\beta\varepsilon)$	1.113358811	
$I_0(\beta)$	1	
$\delta 1 = T1/T2$	0.08071025	

Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
1000	1.52549067	9.00E-02	1.14

Surficial Aquifer Drawdown - 22,304 ft from well pumping 1,000 gpm - Maximum Drawdown Case

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units	Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
Time since beginning of pumping (t)	4.0	years	1000	2.45115841	1.51E-01	1.91
Radial distance from Lower Floridan aquifer pumping well (r)	22304	feet				
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day				
Specific Yield of surficial aquifer (S_1)	0.30000					
Transmissivity of Upper Floridan aquifer (T_2)	11,000	ft^2/day				
Stortivity of Upper Floridan aquifer (S_2)	0.000005					
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day				
Thickness of confining unit (b')	325	feet				
$\nu_1 = T_1/S_1$	5,000	ft^2/day				
$\nu_2 = T_2/S_2$	2,200,000,000	ft^2/day				
$\nu_v = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	10,000	ft^2/day				
$r_e = 1.5(\nu_v t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet				
$B_1 = (T_1/(K'/b'))^{1/2}$	69,821	feet				
$B_2 = (T_2/(K'/b'))^{1/2}$	189,077	feet				
$\beta_1 = r/B_1$	0.31944452					
$\beta_2 = r/B_2$	0.11796271					
$\beta^2 = \beta_1^2 + \beta_2^2$	0.11596000					
β	0.34052901					
$\beta\varepsilon_1 = re/B_1$	0.63888905					
$\beta\varepsilon_2 = re/B_2$	0.23592542					
$\beta\varepsilon^2 = \beta\varepsilon_1^2 + \beta\varepsilon_2^2$	0.46384001					
$\beta\varepsilon$	0.68105801					
$\ln(r_e/r)$	0.693					
$K_0(\beta)$	1.257					
$K_0(\beta\varepsilon)$	0.680809207					
$I_0(\beta\varepsilon)$	1.119365277					
$I_0(\beta)$	1					
$\delta 1 = T1/T2$	0.136363636					

Surficial Aquifer Drawdown - 1 ft from well pumping 1,000 gpm - Minimum Drawdown Case

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units
Time since beginning of pumping (t)	4.0	years
Radial distance from Lower Floridan aquifer pumping well (r)	1	feet
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day
Specific Yield of surficial aquifer (S_1)	0.30000	
Transmissivity of Upper Floridan aquifer (T_2)	36,000	ft^2/day
Stortivity of Upper Floridan aquifer (S_2)	0.01000	
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day
Thickness of confining unit (b')	325	feet
$\nu_1 = T_1/S_1$	5,000	ft^2/day
$\nu_2 = T_2/S_2$	3,600,000	ft^2/day
$\nu_v = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	9,986	ft^2/day
$r_e = 1.5(\nu_v t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet
$B_1 = (T_1/(K'/b'))^{1/2}$	69,821	feet
$B_2 = (T_2/(K'/b'))^{1/2}$	342,053	feet
$\beta_1 = r/B_1$	0.00001432	
$\beta_2 = r/B_2$	0.00000292	
$\beta^2 = \beta_1^2 + \beta_2^2$	0.00000000	
β	0.00001462	
$\beta\varepsilon_1 = re/B_1$	0.63888905	
$\beta\varepsilon_2 = re/B_2$	0.13041268	
$\beta\varepsilon^2 = \beta\varepsilon_1^2 + \beta\varepsilon_2^2$	0.42518668	
$\beta\varepsilon$	0.65206340	
$\ln(r_e/r)$	10.706	
$K_0(\beta)$	11.249	
$K_0(\beta\varepsilon)$	0.713471027	
$I_0(\beta\varepsilon)$	1.109154965	
$I_0(\beta)$	1	
$\delta 1 = T1/T2$	0.041666667	

Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
1000	0.81705280	8.15E-02	9.11

Surficial Aquifer Drawdown - 1 ft from well pumping 1,000 gpm - Basecase

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units	Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
Time since beginning of pumping (t)	4.0	years	1000	1.52549067	1.57E-01	17.64
Radial distance from Lower Floridan aquifer pumping well (r)	1	feet				
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day				
Specific Yield of surficial aquifer (S_1)	0.30000					
Transmissivity of Upper Floridan aquifer (T_2)	18,585	ft^2/day				
Stortivity of Upper Floridan aquifer (S_2)	0.00115					
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day				
Thickness of confining unit (b')	325	feet				
$\nu_1 = T_1/S_1$	5,000	ft^2/day				
$\nu_2 = T_2/S_2$	16,160,870	ft^2/day				
$\nu_v = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	9,997	ft^2/day				
$r_e = 1.5(\nu_v t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet				
$B_1 = (T_1/(K'/b')^{1/2}$	69,821	feet				
$B_2 = (T_2/(K'/b')^{1/2}$	245,767	feet				
$\beta_1 = r/B_1$	0.00001432					
$\beta_2 = r/B_2$	0.00000407					
$\beta^2 = \beta_1{}^2 + \beta_2{}^2$	0.00000000					
β	0.00001489					
$\beta\varepsilon_1 = re/B_1$	0.63888905					
$\beta\varepsilon_2 = re/B_2$	0.18150550					
$\beta\varepsilon^2 = \beta\varepsilon_1{}^2 + \beta\varepsilon_2{}^2$	0.44112346					
$\beta\varepsilon$	0.66417126					
$\ln(r_e/r)$	10.706					
$K_0(\beta)$	11.231					
$K_0(\beta\varepsilon)$	0.699587159					
$I_0(\beta\varepsilon)$	1.113358811					
$I_0(\beta)$	1					
$\delta 1 = T1/T2$	0.08071025					

Surficial Aquifer Drawdown - 1 ft from well pumping 1,000 gpm - Maximum Drawdown Case

$s_1 = (Q_2/2\pi(T_1 + T_2))(\ln(r_e/r)-(K_0(\beta) - K0(\beta\varepsilon)I0(\beta)/I0(\beta\varepsilon)))$ Parameter	Value	Units
Time since beginning of pumping (t)	4.0	years
Radial distance from Lower Floridan aquifer pumping well (r)	1	feet
Transmissivity of surficial aquifer (T_1)	1,500	ft^2/day
Specific Yield of surficial aquifer (S_1)	0.30000	
Transmissivity of Upper Floridan aquifer (T_2)	11,000	ft^2/day
Stortivity of Upper Floridan aquifer (S_2)	0.000005	
Hydraulic conductivity of confining unit (K')	1.00E-04	ft/day
Thickness of confining unit (b')	325	feet
$\nu_1 = T_1/S_1$	5,000	ft^2/day
$\nu_2 = T_2/S_2$	2,200,000,000	ft^2/day
$\nu_v = 2\nu_1\nu_2/(\nu_1 + \nu_2)$	10,000	ft^2/day
$r_e = 1.5(\nu_v t)^{1/2}$ not used, chosen to be 44,608 ft	44,608	feet
$B_1 = (T_1/(K'/b'))^{1/2}$	69,821	feet
$B_2 = (T_2/(K'/b'))^{1/2}$	189,077	feet
$\beta_1 = r/B_1$	0.00001432	
$\beta_2 = r/B_2$	0.00000529	
$\beta^2 = \beta_1^2 + \beta_2^2$	0.00000000	
β	0.00001527	
$\beta\varepsilon_1 = re/B_1$	0.63888905	
$\beta\varepsilon_2 = re/B_2$	0.23592542	
$\beta\varepsilon^2 = \beta\varepsilon_1^2 + \beta\varepsilon_2^2$	0.46384001	
$\beta\varepsilon$	0.68105801	
$\ln(r_e/r)$	10.706	
$K_0(\beta)$	11.206	
$K_0(\beta\varepsilon)$	0.680809207	
$I_0(\beta\varepsilon)$	1.119365277	
$I_0(\beta)$	1	
$\delta 1 = T1/T2$	0.136363636	

Upper Floridan Aquifer Pumping (Q_2 in gpm)	$Q_2/2\pi(T_1+ T_2)$ (ft)	Surficial Aquifer Drawdown (s_1 in feet)	Floridan Aquifer Drawdown (s_2 in feet)
1000	2.45115841	2.65E-01	29.78